

Making of the Intelligent Calculation System for Physical Parameters of Oceanic Internal Waves

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Abstract— For obtaining the physical parameters of oceanic internal waves from MODIS remote sensing images, the intelligent calculation system had been developed based on Multimedia ToolBook. The intelligent calculation system was made according to the characteristics of light stripes and dark stripes in oceanic internal waves. The physical parameters such as the wavelength, the travelling direction, and their uncertainties had been calculated semi-automatically. There were four steps. The first one was that the MODIS remote sensing images would be corrected based on the geographic location of Taiwan Island and the ratio of South-North and East-West of the Dongsha Islands. The second one was that the zones of the oceanic internal waves could be obtained by Photoshop. The third one was that a series of the straight line segments in the crests of the oceanic internal waves could be drawn by Visio system. The finally step was that the wavelength, the travelling direction, and their uncertainties had been calculated by the intelligent calculation system developed in this paper. The conclusion shown that the most wavelengths were in 0.8~2.5km, the travelling direction was in north by west 35~85°, and the maximum crest length of the oceanic internal waves in the North-East of Dongsha Islands was 250km.

Keywords - Information Optics; oceanic internal wave; MODIS; Multimedia ToolBook

I. INTRODUCTION

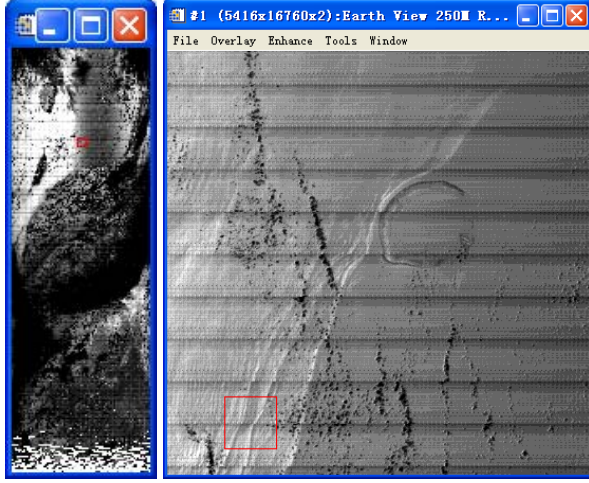
Oceanic internal waves were a wave that was in the stable stratification of the seawater density. The stratification was formed stable layers caused by the temperature and salt structure. Oceanic internal waves occurred when the seawater deviated from equilibrium position caused by the external disturbances. The amplitudes of the oceanic internal waves were 10 meters, a few tens of meters, and even a few hundreds of meters. In 1847, Stocks studied on the interface between two fluids

wave theory. In 1883, Rayleigh studied a continuous of fluid in the internal wave theory. In 1904, Ekman explained the “dead water” phenomenon with drifting theory. The speed of the boat was slowed down as the boat consumed energy generated in the interface between two layers of internal waves. This was the phenomenon of increasing resistance. In 1972, 1975, and 1979, Garrett and Munk put forwarded the spectrum models of oceanic internal waves in the world those were GM72, GM75, and GM79, respectively. The spectrum model included the expressions of energy, wave number, frequency, wavelength, and so on^[1-3]. In latest years, SAR remote sensing images had been used for obtaining the physical parameters of oceanic internal waves^[4-6]. The new method had been put forwarded for obtaining the physical parameters of oceanic internal waves from MODIS remote sensing images in this paper.

II. PRETREATMENT OF THE MODIS REMOTE SENSING IMAGES

Moderate Resolution Imaging Spectroradiometer (Abbreviated as MODIS) was one of the most important remote sensors. The remote sensor was with 36 visible light - infrared spectral bands carried on the EOS series of satellites. The space resolutions were in 250m, 500, and 1000m. A remote sensing image of MODIS at 13:30, July 1, 2008 was shown in Fig. 1. The image could be corrected through pretreatment. The process included rotation based on the direction of Taiwan Island and adjustment based on the ratio of South-North and East-West of the Dongsha Islands. The zones of the oceanic internal waves could be obtained by Photoshop and a series of the straight line segments in the crests of the oceanic internal waves could be drawn by Visio system. There were 7 groups of oceanic internal waves in the handled image at 13:30, July 1, 2008

and 3 groups of oceanic internal waves in the handled image at 13:20, July 3, 2008 shown in Fig. 2. For calculating the physics parameters of the wavelengths and the travelling directions in the oceanic internal waves, the intelligent calculation system will be developed.



(a) MODIS image (b) internal waves
Fig. 1 Oceanic internal waves in a MODIS image

III. MAKING OF THE INTELLIGENT CALCULATION SYSTEM FOR PHYSICS PARAMETERS OF OCEANIC INTERNAL WAVES

According to the characteristics of the MODIS remote sensing images, the distance of two reference segments and the direction of the sensors forward could be decided. One of the characteristics was the dark periodicity stripes leaving each scan.

A. The theoretical basis for the production of software

The oceanic internal waves were very complex because there were many formed causes for the oceanic internal waves. The directions and the distance of the light stripes and dark stripes were different. Fortunately, the spatial resolution of the selected MODIS remote sensing images was 250m and the each pixel expressed 250m. The distance of the two reference straight segments had 40 pixels and the distance was 10km. The wavelength would be decided when the distance of the adjacent measurement segments in image could be found.

(a) Deciding of the distance of the two reference straight segments and the direction of the sensors forward
The two parallel reference segments were drawn in Visio system and the slope k of the segments could be decided. The new straight line was that it crossed the center of the two segments and its slope k_0 was negative reciprocal of the slope k . The length of the two interaction points between the new line and the two reference segments was 10km. If the two reference segments were not parallel, the calculation method was as follow. The two reference segments were called as l_1 and l_2 . The coordinates of the end points were (x_{11}, y_{11}) , (x_{12}, y_{12}) , (x_{21}, y_{21}) , and (x_{22}, y_{22}) . The slopes were

expressed as $k_1 = \frac{y_{11} - y_{12}}{x_{11} - x_{12}}$ and $k_2 = \frac{y_{21} - y_{22}}{x_{21} - x_{22}}$, respectively.

The slope of the angle bisector of two reference segments

$$k_0 = \frac{k_1 k_2 - 1 + \sqrt{(k_1 k_2 - 1)^2 - (k_1 + k_2)^2}}{k_1 + k_2} \quad (1)$$

The coordinates of the center point was

$$x_0 = \frac{x_{11} + x_{12} + x_{21} + x_{22}}{4}, \quad y_0 = \frac{y_{11} + y_{12} + y_{21} + y_{22}}{4}$$

The slope of the new line was $-\frac{1}{k_0}$ and the new line crossed the center point.

$$l_0: y - y_0 = -\frac{1}{k_0}(x - x_0)$$

The coordinates of the two interaction points between the new line and two reference segments were (x_{110}, y_{110}) and (x_{210}, y_{210}) .

$$\begin{cases} x_{110} = \frac{y_0 - y_{11} + k_1 x_{11} + \frac{x_0}{k_0}}{k_1 + \frac{1}{k_0}} \\ y_{110} = y_0 - \frac{1}{k_0}(x_{110} - x_0) \\ x_{210} = \frac{y_0 - y_{21} + k_1 x_{21} + \frac{x_0}{k_0}}{k_2 + \frac{1}{k_0}} \\ y_{210} = y_0 - \frac{1}{k_0}(x_{210} - x_0) \end{cases} \quad (2)$$

The distance of the two interaction points was expressed as

$$d_0 = \sqrt{(x_{110} - x_{210})^2 + (y_{110} - y_{210})^2} \quad (3)$$

The distance was 10km in real space.

(b) Deciding the statistical wavelength and the travelling direction of the oceanic internal waves
For deciding the wavelengths, a series of the straight segments in the crests of the oceanic internal waves could be drawn by Visio system. The coordinates of the end points could be read in Visio system. In the remote sensing images the antinodes number of oceanic internal waves was not large than 6 and it maybe 2, 3, 4, 5, and 6. The programming technique was put forward. It was called cycle assignment method in Multimedia ToolBook as follow for the uncertain n .

step i from 1 to n

```
x[i+2][1]=text of field ("field"&(i+2)&1)
x[i+2][2]=text of field ("field"&(i+2)&3)
y[i+2][1]=text of field ("field"&(i+2)&2)
y[i+2][2]=text of field ("field"&(i+2)&4)
k[i+2]=(y[i+2][1]-y[i+2][2])/(x[i+2][1]-x[i+2][2])
end
```

The method of the center point was used and the new line crossed the center point. The slope of the new line was average of the all slopes in the group. In the group there were n segments, n interaction points, and $n-1$ segments were called as d_1, d_2, \dots, d_{n-1} . The $n-1$ wavelengths could be obtained when d_1, d_2, \dots, d_{n-1} were compared with the distance d_0 between two reference segments. At some time, the travelling direction of the oceanic internal waves could be obtained.

The statistical wavelength and the travelling direction of the oceanic internal waves could be obtained by statistical method. The flowchart of the intelligent calculation system was shown in Fig. 3.

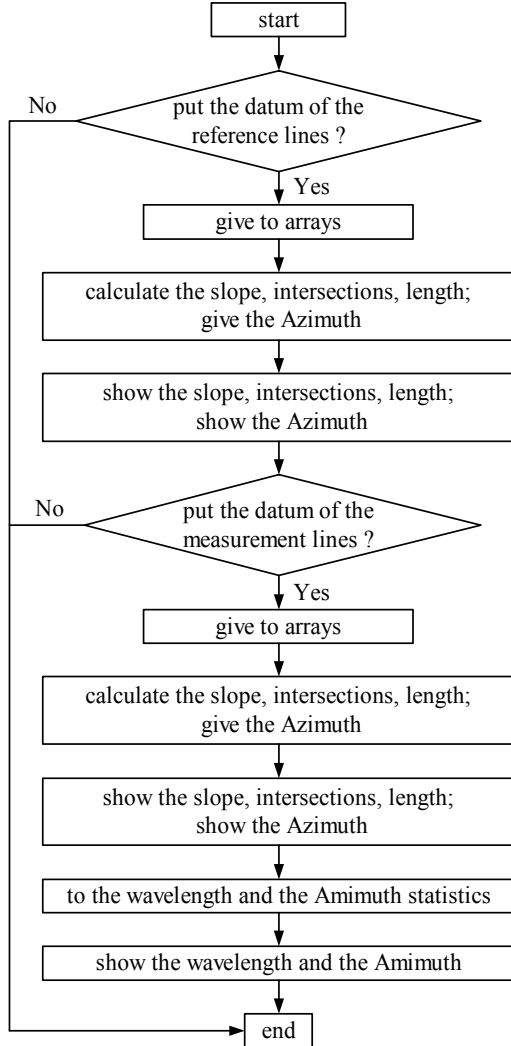


Fig. 3 Flowchart of the intelligent calculation system

B. Making method of the intelligent calculation system for physical parameters of oceanic internal waves

At the top of the interface in Multimedia ToolBook, there was the title of “Intelligent Calculation System for Physics Parameters of Oceanic Internal Wave” shown in Fig. 4. At the left below there was the zone for calculation reference

lines to decide the distance between two reference segments in image and the direction of the sensors forward. The distance was very important because there were 40 pixels between two reference segments. Each pixel was 250m so the distance in real space was 10km. At the right below there was the zone for calculation measure lines to decide the wavelength and the travelling direction of oceanic internal waves in the group. The wavelength was obtained from the ratio between the average distance of the measurement segments and the distance of two reference segments.

IV. EXPERIMENT RESULTS

The end point coordinates of two reference segments in Fig. 2 were put into the fields at the left below as shown in Fig. 3. For a group the end point coordinates of the measurement segments in Fig. 2 were put into the fields at the right below. The calculation results were shown when the button “Calculation” was clicked. The wavelength was (1.7 ± 0.2) km and the travelling direction of oceanic internal waves in the group was $(78 \pm 3)^\circ$. There were 7 groups of oceanic internal waves in Fig. 2(a) and there were 3 groups in Fig. 2(b). The experiment was to 10 times for every group and the results of the wavelengths and the travelling directions were shown in table 1.

In a word, the results the most wavelength of oceanic internal waves in the groups was in 1.3~2.5km. The travelling directions were north-west 35° ~ 85° . If the results were combined with that of the reference [7], the statistical results were shown that the longest wave peaks was up to 250km in North-East of Dongsha Islands. In the zone the most wavelengths of oceanic internal waves was in 0.8~2.5km and the travelling directions was north-west 35° ~ 85° . The result was similar to the reported results [8].

Table 1 Statistical table of the wavelength and the travelling direction of oceanic internal waves in each group

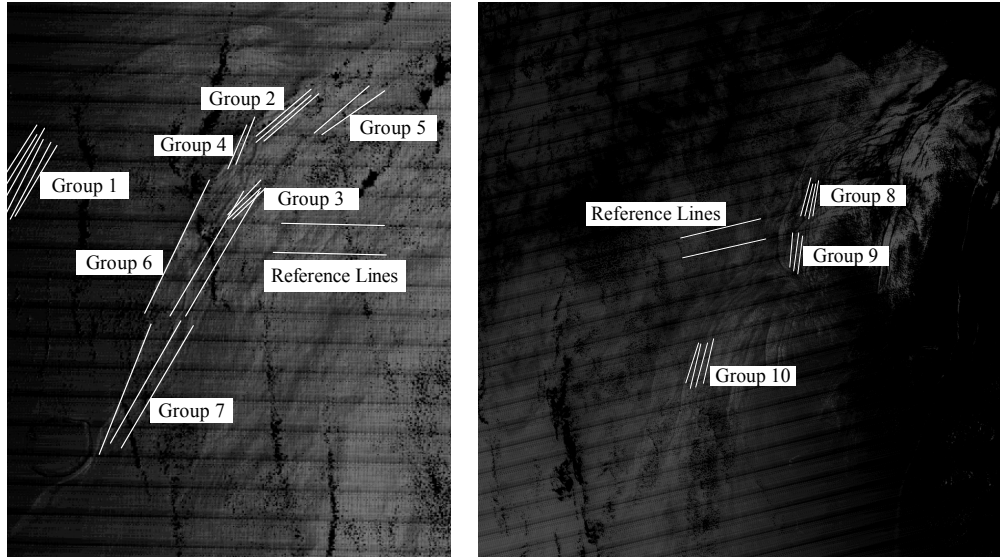
	The number of antinodes	Direction of Wave / north west	Wavelength / km
Group 1	6	$(60 \pm 3)^\circ$	2.0 ± 0.4
Group 2	3	$(45 \pm 2)^\circ$	1.3 ± 0.3
Group 3	3	$(41 \pm 1)^\circ$	1.5 ± 0.2
Group 4	2	$(67.5 \pm 0.7)^\circ$	1.657
Group 5	2	$(38 \pm 3)^\circ$	3.314
Group 6	3	$(63 \pm 5)^\circ$	23 ± 17
Group 7	3	$(61 \pm 3)^\circ$	19 ± 15
Group 8	4	$(78 \pm 3)^\circ$	1.7 ± 0.2
Group 9	3	$(83 \pm 2)^\circ$	2.3 ± 0.2
Group 10	4	$(75 \pm 2)^\circ$	2.5 ± 0.5

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REFERENCES

- [1] DU Tao, FANG Xin-hua, "The influences of internal tides in physical oceanography and in related discipsegments," Marine forecasts. 2003, 20(4):50-55
- [2] QIAN Su-ping, TIAN Li-xin, "Similarity reduction analysis for a coupled KdV system," Communications in theoretical physics. 2007, 48(3): 399-404
- [3] DU Tao, Wu Wei, FANG Xin-hua, "The generation and distribution of ocean internal waves," Marine science. 2001, 25(4): 25-28
- [4] PYO Furue. "Energy transfer within the small-scale oceanic internal waves spectrum," Journal of physical oceanography. 2003, 33: 267-282
- [5] Yang Jing-song, HUANG Wei-gen, ZHOU Chang-bao, et al, "Remote sensing of nonlinear internal wave depth," 2001, ILLMC: 265-267
- [6] K.V. S. R. Prasad, M. Rajasekhar. "Observations of oceanic internal waves in bay of Bengal using synthetic aperture radar," Processing of SEASAR. 2006: 1-6
- [7] JIANG Xing-fang, CHEN Fang-fang, HE Xian-qiang. "Research of the Physics Parameter in Ocean Internal Wave," Acta Photonica Sinica. in press.
- [8] Antony K. Liu, Ming-kuang Hsu. "Nonlinear internal wave study in the south China sea Using SAR," International Journal of remote sensing. 2004, 25: 1261-1264



(a) Internal waves at 13:30, July 1, 2008

(b) Internal waves at 13:20, July 3, 2008

Fig. 2 Figures of oceanic internal waves

Intelligent Calculation System for Physics Parameters of Oceanic internal waves

Reference Lines	I_1	I_2	Measurement Lines	L_1	L_2	L_3	L_4	L_5	L_6
Beginx	67.5	68.5	Beginx	132.5	133.5	135	136.5		
Beginy	34	24	Beginy	64	61	61	62.5		
Endx	107.5	110	Endx	127.5	129.5	131.5	133.5		
Endy	43.5	33.5	Endy	45	45	43.5	45		
Slope	0.238	0.229	Slope	3.8	4	5	5.833		
Center	88.4	33.8	Center	132,53	132,53	132,53	132,53		
Intersection1	87.2	38.7	Intersection x	129.9	131.6	133.4	134.8		
Intersection2	89.5	28.8	Intersection y	53.9	53.5	53.2	52.9		
Length	10.136	mm/10km	Length	1.827	1.836	1.447			mm/10km
Azimuth	13.088	° (North-West)	Azimuth	75.295	76.002	78.73	80.313		° (North-West)
Measurement results: wavelength				1.7	±	0.2	km		
Azimuth				78	±	3	° (North-West)		

Back

Fig. 4 Interface of the intelligent calculation system of the physics parameters in oceanic internal waves